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Efficiency Measurement Model of Projects using DEA

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***Abstract*—This paper presents the efficiency measurement model that has been developed based on data envelopment analysis. The model is intended for products produced by organization, optimizes a ratio of multiple weighted outputs to a multiple weighted inputs, where the efficient unit will have a score of one, and the inefficient unit will have a score less than one. The model is simple yet practical in implementation. Descriptive analysis of the data, model validation and relative efficiency results are presented. It is anticipated that the projects which act as the decision making unit can later be used to determine the efficiency of the company department/unit that housed the projects.**

Keywords-efficiency measurement model; DEA; project efficiency

I. INTRODUCTION

Measuring business performance and presenting the resulting information for action is one aspect of achieving business success. Performance is the results of organization's effort to achieve its goals or objectives [1]. Reference [2] explained that good performance indicates that the organization's practice is working well according to plans while poor performance indicates that practice does not work according to the plans. Efficiency measurement is one of the main components in measuring organizational business performance. Efficiency is measured with a target to the organization's goals for example maximization outputs, maximization of profits or minimization of costs. The theory of efficiency is related to the association between resources used and results achieved. The efficiency measurement deals with the way how an organization uses the resources in a best way to produce output. The optimization of resources can amplify the efficiency and competitiveness of the organization.

Several techniques exist to measure the efficiency of an organization. Among them, the most frequently used approaches are parametric approach and non-parametric approach. Parametric approaches specify functional form and take into account residual term in the analysis while the non-parametric approaches put less structure on the specification of the best practice frontier and assume no random error [3]. The main difference between both approaches is the distribution of the data. Parametric approaches concern with normality of the data distribution while non-parametric approaches do not. There are many advantages of non-parametric method as compared to the parametric ones. For instance non-parametric approaches are simple and less affected by outliers. These approaches do not require information about the distribution and the variance of the data. Besides that, non-parametric methods do not care about the relationship between the sets of the data. Generally, these methods do not require assumption about the data, and can be used in a broader range of data.

Efficiency measurement using non-parametric approach had originated from the attempt to evaluate the efficiency of units that produce multiple outputs with multiple inputs in a situation where input and/or output prices were hardly available [4]. Several types of non-parametric approach are available and among them, is the data envelopment analysis (DEA) which was developed by [5] as a tool for evaluating and improving the performance of manufacturing and service operations.

Data envelopment analysis is a linear programming problem that provides a mean of calculating apparent efficiency levels within a group of organizations. In reference [6], the efficiency of an organization was calculated relative to the group's observed best practice. It was particularly well suited for efficiency evaluation when the organization's efficiency was measured along multiple dimensions. When linked with an adjustment process that accounts for the organization's operating conditions, DEA would produce efficiency scores that neither rewarded organizations that were fortunate enough to operate under favorable conditions nor penalized those that operated under unfavorable conditions [7].

DEA approach was used to estimate the overall, pure technical and scale efficiencies for Malaysian commercial banks during the period 2000-2006 [8]. The results suggested that domestic banks were relatively more efficient than foreign banks. It also suggested that domestic banks' inefficiency were attributed to pure technical inefficiency rather than scale inefficiency. In contrast, foreign banks inefficiency was attributed to scale inefficiency rather than pure technical inefficiency. The study further examined whether the domestic and foreign banks were drawn from the same environment by performing a series of parametric and non-parametric tests. The results from the parametric and non-parametric tests suggested that for the years 2000-

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2004, both domestic and foreign banks possessed the same technology whereas results for 2005 and 2006 suggested otherwise.

Models for measuring the efficiency of decision making unit (DMU) within an organization have been proposed by [9-12]. However, to the best of our knowledge those models were not able to be used to measure business efficiency for product within an organization or company. This study has focused on developing business efficiency measurement model based on product within an organization using DEA approach. DEA is a multi-variable model for measuring the relative efficiency of a homogeneous set of DMUs. The efficiency score for each DMU is equal to a ratio of weighted sum of multiple outputs to weighted sum of inputs, and it is to be maximized as many times as the total number of DMUs. This means that the efficiency scores are computed in the presence of multiple outputs and inputs simultaneously and the weights for inputs and outputs are not unique. Based on the advantages of DEA, this study will employ this technique to develop business efficiency measurement model based on product produced by the DMU of any organization.

For this study, the term DMU is interchangeable with product. Products are projects undertaken by a particular organization. This study will provide a model to measure business efficiency of an organization based on product which will indirectly leads to measuring business efficiency of individual units within an organization.

II. Case Background

The organization that has been used as a case study for the research is In-Fusion Solutions Sdn. Bhd. (ISSB). ISSB offers advanced and innovative e-learning solutions to the global community. ISSB was established in 2002 with the vision of optimizing the technology for learning and new media and to be the premier information and communication technology company, providing virtual education solutions in a full converging environment. ISSB offers advanced and innovative e-learning solutions to the global community. As an education solution and services provider, ISSB core products includes from courseware, enterprise resource planning system for the education environment, educational games, learning content management system, student information management system, integrated campus management system, Islamic banking and finance program, knowledge information exchange system and portal experience.

The selection of DMUs is very crucial in measuring their relative efficiency. This study defines DMUs as the projects in organization that have the same function such as produce product or services. 39 projects were chosen to be analyzed as they are 100 percent completed. The project is divided into two different types which are the hardware projects (H) and courseware projects (C). These data were obtained from company documents such as annual reports and other published documents.

III. Proposed Efficiency Model

The collected data and information were analyzed to determine the inputs and output appropriate to be used in developing the model to measure the efficiency of the DMUs. The general rule of thumb states that the number of DMUs must be more than or equal to three times the sum of inputs and outputs [13].

The selection of input and output will give a big impact to the efficiency model. The measurement model will not be good and resulted in inaccurate results if the chosen input and output are not relevant. Three inputs and one output have been identified as the most appropriate to be included in the efficiency measurement model. The inputs chosen are the labor, material and project duration and the output chosen is the project contract value.

The labor is the total cost (measured in Ringgit Malaysia) of the employee involved in the projects. The labor reflects the sum of all the salaries of the employees involved in completing the project. Employees or persons employed are one of the major components in a project. The project is completed with the cooperation between the employees in finishing the task. Thus, the cost of the employees involved in the projects is considered a significant component in determining the efficiency of the project.

Material is another input that is considered significant in developing any project. Material in this context is the total cost of equipments such as the software and hardware used in the projects. The equipment cost includes the cost of equipment rental and the purchase of new equipment. This is also measured in Ringgit Malaysia. The materials used in one project are assumed differ from other projects.

Projects must be completed in the stipulated time frame. Delay in project completion will cause loss to the organization. Thus the project duration is one of the important factors that need to be considered as the input in this efficiency model. Project duration is measured in months.

The contract value is chosen as the output because it reflects the revenue obtained by the company. There is no other variables/data that can best describe the value of the project. Table I shows the list of the 39 projects with the respective inputs and output.

TABLE I. DATA INPUTS AND OUTPUT FOR EFFICIENCY ANALYSIS OF PROJECTS

Project	Input			Output
	Labor (RM)	**Material (RM)**	**Project Duration (Months)**	**Contract Value (RM)**
H1	90,000.00	2,385,547.20	6	2,650,608.00
H2	480,000.00	673,058.00	24	1,346,116.00
H3	6,000.00	895,233.60	1	1,053,216.00
H4	6,000.00	950,000.00	1	1,000,000.00
H5	48,000.00	5,000.00	3	190,305.00
H6	3,000.00	169,960.50	0.25	188,845.00
H7	3,000.00	151,893.90	0.25	168,771.00
H8	3,000.00	129,933.90	0.25	144,371.00
H9	15,000.00	80,000.00	0.25	149,250.00
H10	15,000.00	63,129.50	0.25	74,270.00
H11	6,000.00	59,376.75	0.25	69,855.00
H12	20,000.00	55,827.20	2	69,784.00
H13	12,000.00	3,000.00	1	42,800.00
H14	3,000.00	17,918.85	0.25	21,081.00
C1	600,000.00	0.00	12	1,000,000.00
C2	473,450.00	0.00	24	557,000.00
C3	1,190,000.00	0.00	12	1,400,000.00
C4	290,700.00	0.00	12	342,000.00
C5	670,548.00	0.00	12	788,880.00
C6	36,000.00	0.00	12	513,218.00
C7	7,000.00	0.00	2	237,125.00
C8	15,000.00	0.00	2	101,214.00
C9	12,000.00	0.00	3	100,000.00
C10	48,000.00	0.00	12	99,900.00
C11	60,000.00	0.00	6	90,000.00
C12	60,000.00	0.00	6	75,000.00
C13	15,000.00	0.00	3	70,000.00
C14	40,000.00	0.00	6	45,000.00
C15	15,000.00	0.00	1	43,890.00
C16	12,000.00	0.00	4	30,200.00
C17	20,000.00	0.00	1	28,000.00
C18	12,000.00	0.00	1	20,000.00
C19	17,000.00	0.00	0.5	19,550.00
C20	5,000.00	16,515.00	3	18,350.00
C21	15,000.00	0.00	1	15,000.00
C22	10,000.00	0.00	1	13,035.00
C23	9,000.00	0.00	0.5	10,000.00
C24	6,000.00	0.00	3	7,500.00
C25	9,000.00	0.00	2	9,800.00

A simple and easy way to measure efficiency of a unit or DMU which have one input and one output is to determine the ratio of output to the input. The general efficiency measure is given by:

$$\text{Efficiency} = \frac{\text{output}}{\text{input}}$$

The efficiency increases as the output value gets larger and the input gets smaller. However, in reality organization operates with the used of multiple inputs to produce multiple outputs. This becomes the drawback of efficiency measure which cannot utilize the situation where there is more than one input or more than one output. To overcome the problem, DEA has been used in this to measure efficiency that involves multiple inputs and single output.

Using DEA, the choice of optimal system of weights for a jth project involves solving a mathematical optimization model whose decision variables are the weights associated with each output and input. Various formulations have been proposed such as ratio, additive, multiplicative, Charnes, Cooper and Rhodes (CCR) and Banker, Charnes and Cooper (BCC) models. However, this study focuses on CCR model developed by [5].

The CCR model formulated for jth project takes the form

$$\text{maximize} \quad \frac{w_1 y_{1j}}{\sum_{i=1}^{3} v_i x_{ij}} \tag{1}$$

subject to

$$\frac{w_1 y_{1j}}{\sum_{i=1}^{3} v_i x_{ij}} \le 1, \qquad \forall j, j = 1, \ldots, 39 \tag{2}$$

$$\text{and} \qquad w_1, v_i \ge 0, \tag{3}$$

where

w_1 = weight for output of type 1 of jth project,
y_j = amount of output of type 1 of jth project,
v_i= weight of input of type i of jth project,
x_{ij} = amount of input of type i of jth project,
w_1 and $v_i \ge 0$, for $j = 1\ldots,39$ and $i = 1,\ldots,3$.

The objective function (1) and constraints (2) and (3) composed of fractions and need to be transformed into linear form so that the model can be solved using simple linear programming. The proposed model is simple and practical in implementation and it is hope that the projects which act as the DMU can later be used to determine the efficiency of the company department/unit that housed the projects. The following section shows the validation of the model and analyzes the raw data as well as the experimental results.

IV. EXPERIMENTAL RESULTS AND ANALYSIS

The summary of the data is shown in Table II and it could be observed that the mean, maximum and minimum labor used is RM 111,735.84, RM 1,190,000.00 and RM 3,000.00 respectively. The mean for material is RM 145,035.75 with the maximum value of RM 2,385,547.20 and the minimum is RM 0.00. As for project duration, the mean, maximum and minimum are 4 months and 3 weeks, 24 months and 1 week respectively. The mean for project contract value is RM 328,306.00 ranging from RM 7,500.00 to RM 2,650,608.00.

TABLE II. SUMMARY FOR INPUTS AND OUTPUT DATA

	Labor (RM)	Material (RM)	Project Duration (Months)	Contract Value (RM)
Maximum	1,190,000.00	2,385,547.20	24	2,650,608.00
Minimum	3,000.00	0.00	0.25	7,500.00
Mean	111,735.84	145,035.75	4.66	328,306.00
Std. Deviation	243,069.04	427,092.22	5.989	538,036.73

Reference [14] states that all inputs used must be related to the output produced to ensure the validation of DEA model. Correlation analysis is suitable in analyzing the data, testing the pattern and checking the relationship between the two variables.

The correlation test is used to study the changes in the value of dependent variable when the value of independent variable changes [15]. Table III shows the correlation relationship between the inputs and the output. The analysis shows that both labor and material have high correlation value, *r*, and large *p* value at significant level of 0.01 level (2-tailed). Although the *r* value between project duration and project contract value is 0.457 (medium correlation) which is below 0.5, it is still can be accepted because the significant level is at 0.01 level (2-tailed). Thus, it can be concluded that there are strong relationships between the independent variables and dependent variable and there are strong correlation relationships between all inputs and the output.

TABLE III. CORRELATION RELATIONSHIP BETWEEN INPUTS AND OUTPUT

Correlation					
		(I) Labor	(I) Material	(I) Project Duration	(O)Contract Value
(I) Labor	Pearson Correlation	1	-.019	.680**	.526**
	Sig. (2-tailed)		.908	.000	.001
(I) Material	Pearson Correlation	-.019	1	.063	.822**
	Sig. (2-tailed)	.908		.703	.000
(I) Project Duration	Pearson Correlation	.680**	.063	1	.457**
	Sig. (2-tailed)	.000	.703		.003
(O) Contract Value	Pearson Correlation	.526**	.822**	.457**	1
	Sig. (2-tailed)	.001	.000	.003	

a. **Correlation is significant at the 0.01 level (2-tailed)
b. I:Input, O:Output

The relationship between inputs such as labor with project duration shows quite high correlation value (r = 0.680) while material with project duration shows low correlation value (r = 0.063) and labor and material shows negative correlation value (r = -0.019). In real situation, it should be no relationship between inputs variables. This is because the correlation value obtained is just a numerical value and meaningless for relationship between all the inputs. If there is high relationship between the inputs, so one of the inputs needs to be eliminated in order to ensure there is no data overlapping [14].

Table IV shows the results of efficiency scores for efficient projects (score = 1) and inefficient projects (score < 1). From the results, only three projects, H3, H9 and C7, out of 39 projects are efficient, where H3 is at the first ranking, followed by H9 and C7. There are 36 projects which are not efficient with efficiency scores range from 0.037 to 0.984. Project C24 is the most inefficient project with the lowest efficiency score which is 0.0367. This condition happens because there is no balance between the three inputs used with the output produced. Project C24 is the project with the lowest contract value but the cost of labor used is high and the project duration is long. The same situation took place for other inefficient projects but with relatively different degree of seriousness. The inefficient projects with high scores would have little unbalance as compared to projects that have very low efficiency scores.

TABLE IV. RELATIVE EFFICIENCY SCORE OF PROJECTS

Rank	Project	Score	Rank	Project	Score
1	H3	1	21	C19	0.330
2	H9	1	22	C9	0.281
3	C7	1	23	C4	0.240
4	C3	0.984	24	C17	0.236
5	H4	0.949	25	H12	0.218
6	H6	0.893	26	C13	0.197
7	H7	0.876	27	C2	0.196
8	H8	0.860	28	C18	0.169
9	H1	0.788	29	C23	0.169
10	C1	0.703	30	C21	0.127
11	H11	0.668	31	C11	0.127
12	H10	0.599	32	C22	0.110
13	C5	0.554	33	C12	0.105
14	H5	0.524	34	C20	0.099
15	C8	0.427	35	C16	0.074
16	C6	0.421	36	C10	0.070
17	H14	0.392	37	C14	0.063
18	C15	0.370	38	C25	0.041
19	H2	0.349	39	C24	0.037
20	H13	0.348			

On the contrary, the inputs used by the efficient projects are relatively balance with the output, the projects contract value. For example, for project H3, the contract value for the project is RM 1,053,216.00. This means that project H3 used minimum cost of labor and material and completed the project in a period of only 1 month. This shows that inputs resources used in the projects are balanced and controllable. The same situation can be observed for projects H9 and C7.

Projects H3, H9, and C7 with relative efficiency scores 1 can be classified as efficient because these projects could balance the input used with output produced, were able to produce maximum output from a given set of inputs or to use a combination of minimum inputs to achieve desired output and used labor, material and project duration efficiently in the production of output. Meanwhile, the other 36 projects with relative efficiency scores less than 1 and classified as inefficient because these projects had unbalance inputs and output and used excess resources in order to produce the output. They were not using labor, material and project duration efficiently in the production of output. The durations of project to complete were always longer and the contract values were not high.

V. CONCLUSION

The projects which are efficient used inputs with the right and ideal quantity to produce the output while the projects which are not efficient used inputs in excess quantity and made the organization's expenses increase. Therefore, the inefficient projects need to be improved by increasing its efficiency score so that inefficient projects can be transformed to be efficient.

In order to improve or increase the project's efficiency, management should reduce the inputs so that it can be balanced with the output production. Management also should find a way to reduce cost of labor, material and project duration in details without disturbing the production of output.

This research has revealed that organization's performance can be measured not only by analyzing the organization's business units but also by analyzing the projects produced by each business unit. The efficiency measurement model for products produced by organization has been developed. The model is simple and practical in implementation. The projects which act as the decision making unit can later be used to determine the efficiency of the company department/unit that housed the projects.

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